IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 23, Issue 3 Ser. 4 (March. 2024), PP 01-08
www.iosrjournals.org

Color Reproduction Of Two Lithium Disilicate Ceramic Crowns With Two Margin Thickness With Glass Ionomer Cement - In Vitro Study

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Abstract:
Background*: Lithium disilicate ceramics gained wide popularity due to their superior esthetics and good mechanical properties but the cementation process using resin cements is associated with technique sensitivity.*
Many trials using glass ionomer as cement took place but no sufficient evidence is available on color reproduction.
Materials and Methods*: In this In-vitro study 32 samples will be divided into two groups according to margin thickness. Group I margin thickness 1mm n=16,Group II margin thickness 1.5mm n=16.*
Each group will be subdivided into two sub-groups according to the type of lithium disilicate. Subgroup (E) Emax n=8 and Subgroup (T) Tessera n=8.
*Preparation of 2 centrals typodonts according to criteria of all ceramic preparation with finish line 1mm and 1.5mm then an impression is taken for duplication ,Duplication of the typodonts using epoxy resin for the production of dies, then scanning of each die and milling of lithium disilicate crowns. Color measurement each crown will be measured for L*a*b* parameters*
Cementation of all ceramic crowns to their perspective dies using glass ionomer cement according to the manufacturer instructions followed by measuring of color parameters then thermocycling of all samples will be done and premeasuring of color parameters Then finally all data will be collected and statistically analyzed.
Results*: the emax has higher values of color change (ΔE) than tessera which was statistically insignificant in 1mm thickness but statistically significant in 1.5mm thickness*
the change of color (ΔE) in both materials was higher in 1mm than 1.5mm,it was insignificant in emax but significant in tessera.
Conclusion: *Regarding the effect of material:In this study the emax has higher values of color change (ΔE) than tessera which was statistically insignificant in 1mm thickness but statistically significant in 1.5mm thickness*
Regarding the effect of marginal thickness:In this study the change of color (ΔE) in both materials was higher in 1mm than 1.5mm,it was insignificant in emax but significant in tessera.
Key Word*: Lithium disilicate; Advanced lithium disilicate; Glass ionomer; Color reproduction .*

Date of Submission: 09-03-2024 Date of Acceptance: 19-03-2024

I. Introduction

Lithium disilicate (SiO_2-Li_2O) was first introduced as a core material with both high translucency and high flexural strength when compared to older leucite-based ceramics. Due to its promising properties, more improvements were done to the material allowing more uniform distribution of the crystals and production of smaller crystals; allowing its use in monolithic restorations. It comes as blue machinable blocks with moderate hardness and strength then it undergoes full crystallization after milling and heat treatment since 2006, the popularity of IPS e.max CAD as a lithium disilicate reinforced ceramic has been almost incomparable. Although several new materials have been introduced since then, IPS e.max proved its superiority as a monolithic restoration in terms of CAD/CAM fabrication, esthetic, mechanical and physical properties. In this study, the new ceramic material to be evaluated is CEREC Tessera.

II. Material And Methods

An in-vitro study comparing color reproduction of two lithium disilicate ceramic crowns with two margin thickness with glass ionomer cement.
Study Design: in-vitro study

Study Location: Ain shams university ,done in Department of Fixed prosthodontics.

Study Duration: September 2022 to January 2024.

Sample size: 32 samples.

Sample size calculation: A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference would be found in color reproduction between different tested groups. By adopting an alpha level of (0.05) a beta of (0.2) i.e. power=80% and an effect size (f) of (0.626) calculated based on the results of a previous study. ; the predicted sample size(n) was a total of (32) samples (i.e. 16 samples per group and 8 samples per subgroup.

Subjects & selection method: In this in vitro study, 32 samples will be divided into two groups according to margin thickness.
Group I margin thickness 1mm n=16
Group II margin thickness 1.5mm n=16
Each group will be subdivided into two sub-groups according to the type of lithium disilicate.
Subgroup (E) Emax n=8
Subgroup (T) Tessera n=8

Inclusion criteria:
No inclusion criteria

Exclusion criteria:
No exclusion criteria

Procedure methodology

Preparation of 2 central incisors typodonts according to criteria of all ceramic preparation with finish line 1mm and 1.5mm using diamond depth cutters of 0.5 mm thickness two times in order to obtain 1mm thickness and 3 times in order to obtain 1.5mm thickness followed by diamond burs in between each depth cutter for smoothening and preparation of the tooth surfaces. initial form of preparation was obtained using medium fine grit (107-126 µm) (MFG) size 016 form 850, followed by fine grit (40 µm) (FFG) size 016 form 850, finally super fine grit (20 µm) (SSFG) size 016 form 850 was used, to draw a shoulder margin all around (labial, axial, palatal), preparation of palatal fossa was done using flame diamond bur, incisal clearance of 1.5mm was obtained and 6o axial wall convergence, A surveyor was used so that the long axis of the tooth was parallel to the bur to mantain the same angle of convergence for all preparations, A putty index was taken before prep to ensure sufficient thickness all around, finshing was then applied

Impression is taken for duplication using putty material for the two thicknesses.

Putty and light impression using Zermack Zetaplus condensation silicone by 2 step techniques for the 2 thicknesses by the same operator.

Duplication of typodonts: using cold cure acrostone acrylic material was poured inside impression material for the production of the 32 dies.

The dies were scanned by MEDIT T310 and was done by the same dental technician, all the dies were sprayed by D-scan spray dentify prior to scanning

Central crown designs were done by the same dental technician for all scans using Exocad software (DentalCAD 3.0 Galway) and utilizing the same library

IPS e.max CAD and tessera CAD blocks (shade of A2) were selected for the fabrication of lithium disilicate crowns. Appropriate grinding instruments were selected and mounted in the milling unit (Step-bur 12s and Cylinder bur 12s).

Suitable grinding instruments , low speed and light pressure were used in finishing and adjusting IPS e.max CAD crowns to prevent chipping at the edges and to prevent also overheating. This was done while the crowns were still in their pre-crystallized (blue) state in case of emax not tessera.

Each crown was then checked on its corresponding die and given a serial number. The restorations were thoroughly cleaned before further processing to remove any residue of the milling since any remaining on the surface may result in bonding problems and discoloration.

Crystallization, glazing and firing were done for lithium disilicate crowns meanwhile glazing and firing were done for advanced lithium disilicate crowns

Freshly glazed specimens were introduced into the Programat EP 3010 furnace (Ivoclar Vivadent, Schaan, Liechtenstein).

Finally, the thicknesses of the specimens were checked using a digital caliper. Color measurement of each crown was measured for L*a*b* parameters using spectrophotometer vita easyshade advance 4.0.

Measurements before cementation:

Color stability: all 36 crowns were placed on dies then were measured for color stability using a Vita Easyshade spectrophotometer Advance 4.0.

The spectrophotometer was calibrated as per the manufacturer's instructions, specifically in the calibration slot, to ensure the accuracy of each measurement. The device was set to restoration mode. Using the Vita Easyshade spectrophotometer, the aperture was positioned centrally on the center of each crown, and the command was given to measure the CIELAB (Commission Internationale de l'Eclairage) coordinates (L*, a*, and b*) for all 36 crowns. Three measurements were taken for each coordinate of every specimen, and the average values were recorded.

The color changes (ΔE) of the samples were assessed using the following equation: ΔECIELAB = (ΔL2 + Δa2 + Δb2) ½. In this formula, L represents lightness on a scale of 0 to 100, a* represents the change in color along the red/green axis, and b* represents the color variation along the yellow/blue axis.

Each crown was cemented to its corresponding cast by Fuji I capsules , which is self-cured conventional glass ionomer cement using light finger pressure until initial setting then any excess cement was removed.

Before undergoing thermal cycling, the samples were stored in distilled water at a temperature of 37 ºC for 24 hours, following the recommendations of the International Organization for Standardization (ISO). The specimens were then subjected to 5000 thermocycles in a thermal cycling simulation machine, with temperature variations between 5°C and 55°C in water, simulating oral conditions over a period of six months. The dwell time, which refers to the immersion time in each bath, was set to 30 seconds, while the transfer time between baths was 5 seconds.

Measurement after cementation and hydrothermal aging color stability was measured using the vita easyshade spectrophotometer advance 4.0 after cementation and hydrothermal aging, and the results were recorded in a similar manner as mentioned previously.

Statistical analysis

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution and using Shapiro-Wilk's test. Data showed parametric distribution and were analyzed using two-way ANOVA. The comparisons of simple effects were made utilizing the pooled error term of the two-way model with p-values adjustment using Bonferroni correction. The significance level was set at $p<0.05$. Statistical analysis was performed with R statistical analysis software version 4.3.2 for Windows .

III. Result

Intergroup comparisons, mean and standard deviation values of color change (ΔE) for different materials within each thickness are presented in table () and in figure ()

1.0 mm:
Emax (8.05±1.01) had a higher value than Tessera (7.64±1.71) yet the difference was not statistically significant (p=0.553).

1.5 mm:
Emax (6.76±1.77) had a significantly higher value than Tessera (3.19±1.00) ($p<0.001$).

Table no 1 shows Intergroup comparisons, mean and standard deviation values of color change (ΔE) for different materials within each thickness.

Material / Thickness	Color change (ΔE) (Mean±SD)		p-value
	Emax	Tessera	
1.0 mm	8.05±1.01	7.64±1.71	0.553ns
1.5 mm	6.76±1.77	3.19±1.00	<0.001*

*; significant ($p<0.05$) ns; non-significant ($p>0.05$).

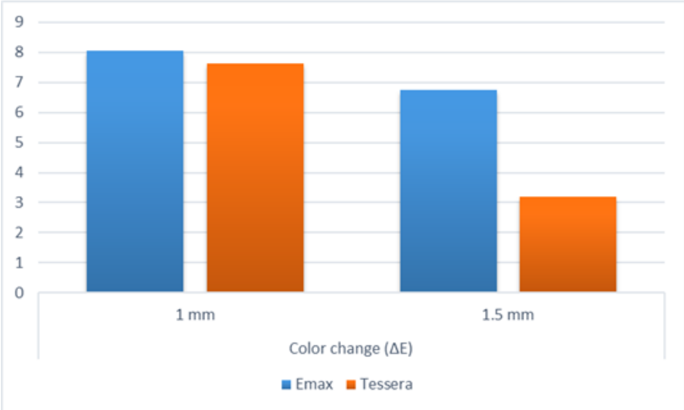

Figure (1): Bar chart showing average color change (ΔE) for different materials within each thickness.

B- Effect of marginal thickness:

Intergroup comparisons, mean and standard deviation values of color change (ΔE) for different marginal thicknesses within each material are presented in table () and in figure ()

Emax:

1.0 mm thick samples (8.05±1.01) had a higher value than 1.5 mm thick samples (6.76±1.77) yet the difference was not statistically significant (p=0.077).

Tessera:

1.0 mm thick samples (7.64±1.71) had significantly higher value than 1.5 mm thick samples (3.19±1.00) (p<0.001).

Table no 2 shows Intergroup comparisons, mean and standard deviation values of color change (ΔE) for different marginal thicknesses within each material.

Thickness / Material	Color change (ΔE) (Mean±SD)		p-value
	1.0 mm	1.5 mm	
Emax	8.05±1.01	6.76±1.77	0.077ns
Tessera	7.64±1.71	3.19±1.00	<0.001*

*; significant (*p*<0.05) ns; non-significant (p>0.05)

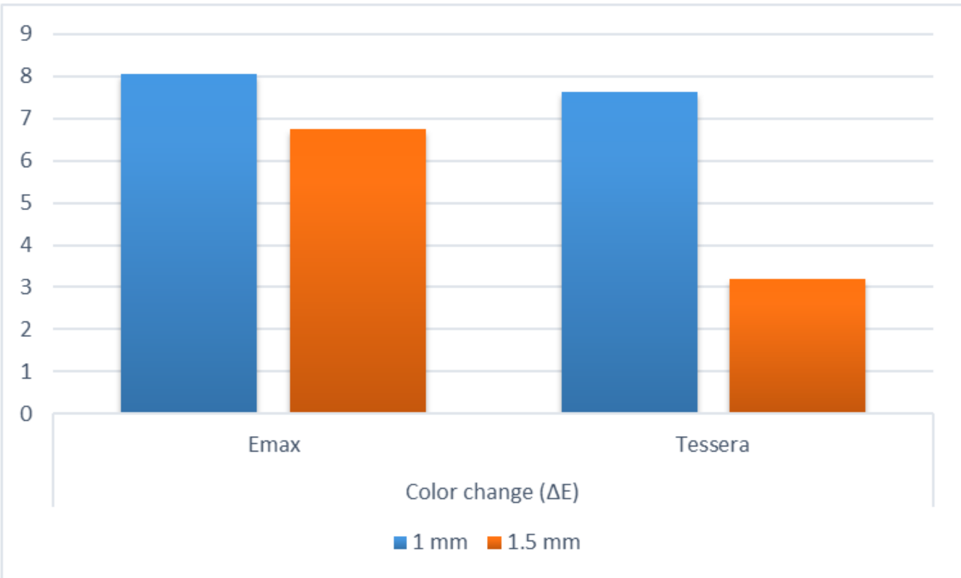

Figure (2): Bar chart showing average color change (ΔE) for different marginal thicknesses within each material.

IV. Discussion

lithium disilicate ceramic material is highly regarded as one of the most significant advancements in ceramic materials due to its exceptional durability and superior esthetics. IPS E-max ceramics, in particular, have achieved remarkable results in replicating the natural tooth appearance and structure by effectively incorporating light diffusion, color, and translucency.(70)

A recent advancement in glass-matrix ceramics lead to the introduction of advanced lithium disilicate (ALDS) glass ceramic, commercially known as CEREC Tessera by Dentsply Sirona. This ceramic incorporates lithium aluminum silicate crystals called virgilite within its glassy zirconia matrix. The manufacturer claims that during the firing process, new virgilite crystals are formed, enhancing the materials strength and esthetic properties. Notably, ALDS offers the advantage of reduced firing time, as short as 4 minutes and 30 seconds, when using the appropriate chairside induction furnace (CEREC SpeedFire by Dentsply Sirona). However, it is still possible to achieve the desired firing of the material using a conventional furnace.(1)

The color of dental restorations holds significant importance for patients, particularly in the visible anterior region of the mouth, as it greatly influences their perception of how well the restorations match their natural teeth. Consequently, there has been a growing preference for porcelain restorations. These restorations offer a compelling combination of excellent esthetic appearance, high patient satisfaction, and biocompatibility.(71)

Prior research investigating the color of dental ceramics has indicated that color change values below 3.7 are considered clinically acceptable. Also according to **Sybasi et al.** (72) So the same values were established as the limit for color change in the present study.

This invitro study was performed to offer standardized and optimized conditions in terms of the 1.preparation design 2.impression technique 3.experimental performance of the studied materials.(73)

In this study we used dental typodonts acrylic model (Banna dental cast, Egypt) a non-metal model was used to simulate the refractive index of natural teeth, this choice aimed to replicate the optical properties of natural teeth accurately while avoiding any interference from metal artifacts.(74,75)

In this study we used condensation silicone material which was used for duplicating the models to ensure accuracy and dimensional stability

Acrostone acrylic material (cold cure) had been used in this study as it’s easy to use and mix and also because its available in multiple shades so that it won’t affect the results of the study

In order to replicate real clinical conditions, finishing and polishing procedures were performed on the specimens. However, these procedures were kept to a minimum to avoid any negative impact on the microstructure. A standardized sequential minimal finishing and polishing protocol, consistent with protocols used by other researchers and in accordance with manufacturer instructions, was followed to ensure uniformity among all specimens.(76)

Dental surveyor was used to ensure standarlized tooth preparation, a modified surveyor with a suspension arm was employed. This allowed for precise control of the handpiece orientation during the preparation process. The movable table of the surveyor was adjusted to secure the dentoform maxillary dental arch, aligning the long axis of the tooth parallel to the bur. This setup ensured a uniform angle of convergence for all preparations, facilitating standardized tooth preparation.(77)

The study utilized CAD/CAM lithium disilicate ceramic blocks, which were selected due to their standardized manufacturing process. This process ensures that the blocks have a more uniform structure, consistent quality, and improved mechanical and physical properties.

In this study, the utilization of 5-axis milling machines(MCXL) was based on the successful outcomes demonstrated by previous research conducted by **Lerner et al**.(78) and **Revilla-León et al.** (79). These studies provided evidence of the machines' ability to accurately reproduce a precise fit and accurate surface anatomy. Hence, the decision to employ 5-axis milling machines in this particular study was made.

In this study, a model was scanned using an extraoral scanner (MEDIT T310) to create a duplicate. Extraoral scanners operate by continuously capturing the model using laser projection and recording the reflections, while intraoral scanners scan incrementally, resulting in a stitched image that may introduce errors (80). Therefore, intraoral scanning can be challenging due to space restrictions, which may require segmental capture of the area and further introduce errors (81). **Flügge et al**. (80) conducted a study that reported higher precision with extraoral scanning compared to intraoral scanning, attributed to the need for additional scans from multiple angles. Similarly, other studies by **Atia et al**.(82)

Regarding the cementation resin cement was always the method of choice but lately due to its technique sensitivity more studies were considered to overcome this disadvantage also **Hölken et al** (36) stated that because the flexural strength of the ALD ceramic considerably exceeds that of other silicate ceramics. This is why it can be both adhesively bonded and conventionally cemented. Also in an invitro study by **Mobilio et al**(83) it was observed that lithium disilicate full crowns, when cemented with luting composite, exhibited higher failure loads in comparison to conventional cementation using glass-ionomer cement, within the limitations of the study.

Spectrophotometry is a quantitative method employed in dentistry to measure color accurately (84). In dental research, the Vita Easyshade spectrophotometer is frequently utilized to obtain CIELAB coordinates.(85) In our study, we employed this instrument to determine the ΔE values for the crowns. Spectrophotometers have been shown to offer a 33% increase in accuracy and a more objective color match in 93.3% of cases compared to human visual observations or conventional techniques. Additionally, spectrophotometers have a longer lifespan than colorimeters and are not affected by object metamerism.(86)

When assessing the optical properties of ceramics, it is common for studies to immerse the samples in artificial saliva and various beverages. Additionally, some studies subject the materials to thermocycling, simulating the oral environment by exposing them to different temperatures and multiple cycles (93). In this particular study, a total of 5,000 cycles were selected to represent a timeframe of 6 months in the oral environment.

V. Conclusion

Within the limitations of this in vitro study the following conclusions could be drawn.
Regarding the effect of material:

In this study the emax has higher values of color change (ΔE) than tessera which was statistically insignificant in 1mm thickness but statistically significant in 1.5mm thickness regarding the effect of marginal thickness:

In this study the change of color (ΔE) in both materials was higher in 1mm than 1.5mm,it was insignificant in emax but significant in tessera.

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